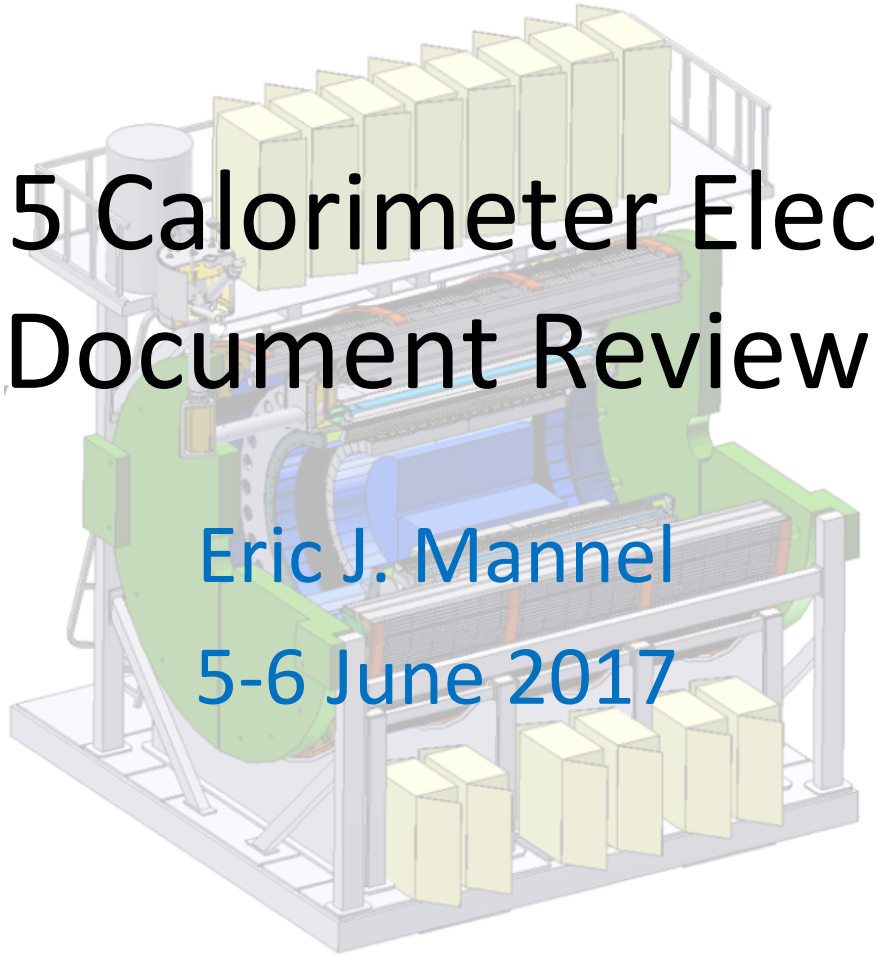
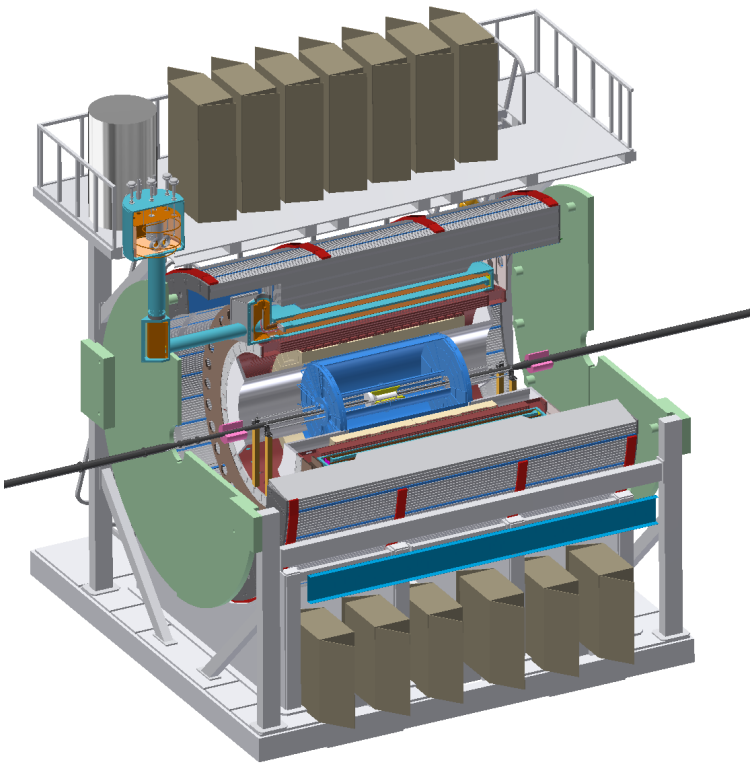
WBS 1.5 Calorimeter Electronics Document Review



Eric J. Mannel

5-6 June 2017

WBS 1.5: Calormeter Electronics

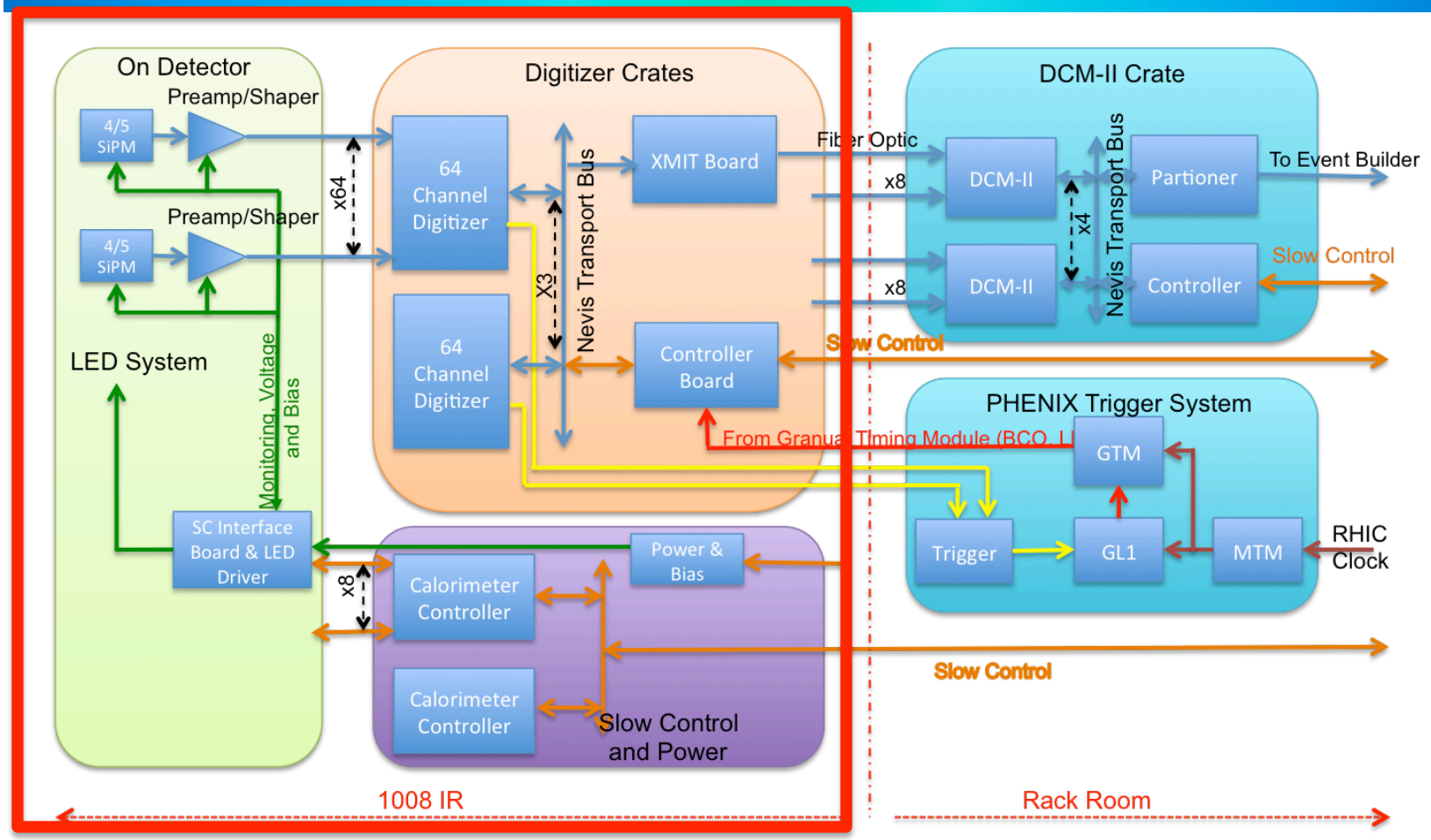


WBS	sPHENIX MIE Project Elements
1.1	Project Management
1.2	Time Projection Chamber
1.3	Electromagnetic Calorimeter
1.4	Hadron Calorimeter
1.5	Calorimeter Electronics
1.6	DAQ-Trigger
1.7	Minimum Bias Trigger Detector

WBS	Infrastructure & Facility Upgrade
1.8	SC-Magnet
1.9	Infrastructure
1.10	Installation-Integration

WBS	Parallel Activities
1.11	Intermediate Silicon Strip Tracker
1.12	Monolithic Active Pixel Sensors

Electronics Overview



WBS 1.5 Scope

- WBS 1.5.1 Optical Sensors: Procure, test and sort all optical sensors (SiPMs) for the EMCal and HCal preproduction and production Detectors
- WBS 1.5.2 Front End Electronics: Procure components, assemble and Q/A all front end EMCal and HCal electronics, including on-detector cables and power systems for preproduction and production detectors.
- WBS 1.5.3: Calorimeter Digitizers: Procure components, assemble and Q/A digitizer system for the EMCal and HCal detectors including signal fibers and power systems for preproduction and production detectors.

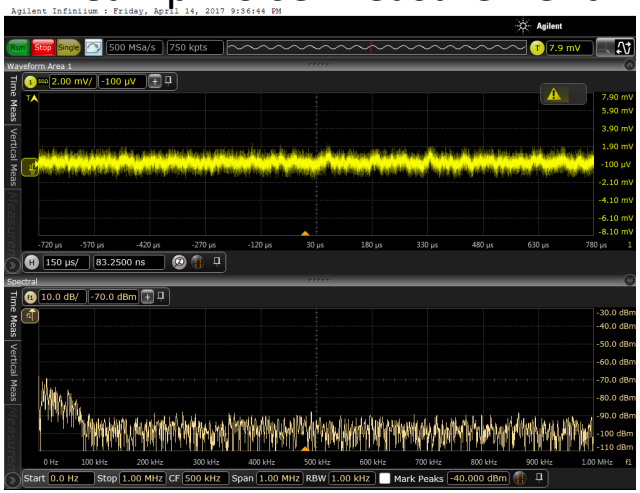
WBS 1.5 Deliverables

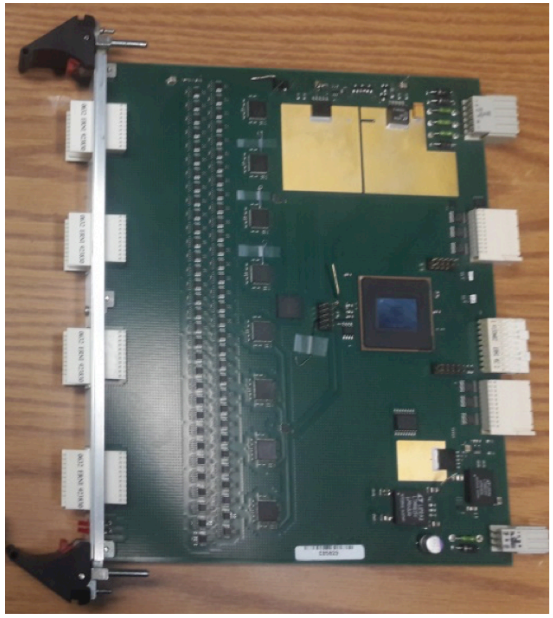
- WBS 1.5.1 Optical Sensors
  - 1800 SiPMs for preproduction prototype EMCal and HCal Detectors
  - 113K SiPMs tested and sorted for Production EMCal and HCal detectors
- WBS 1.5.2 Front End Electronics
  - 384 Channels preproduction EMCal channels
  - 96 Channels preproduction HCal channels
  - 24576 Channels of EMCal production channels
  - 3072 Channels of HCal production channels
  - Slow controls, signal cables, power cables, power systems, and LED calibration system.
- WBS 1.5.3 Digitizer System
  - 27648 channels of digitzers meeting sPHENIX readout requirements
  - Timing interface to sPHENIX timing system
  - Power supplies

WBS 1.5 Prototypes

- Most devices in advanced stage of development
- Cost estimates based on prototype designs
- Analog modules used as part of T-1044
- Low technical risk

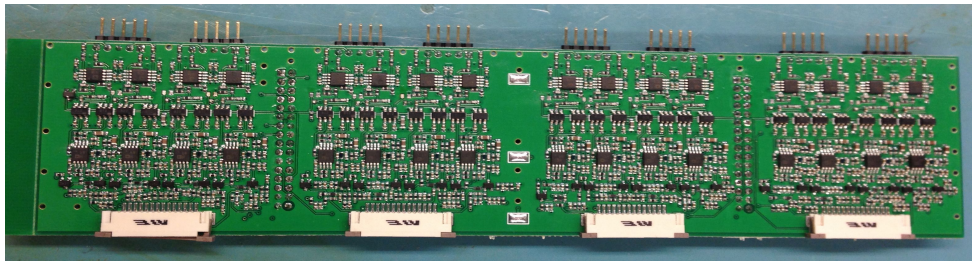
Preamp Noise Measurement



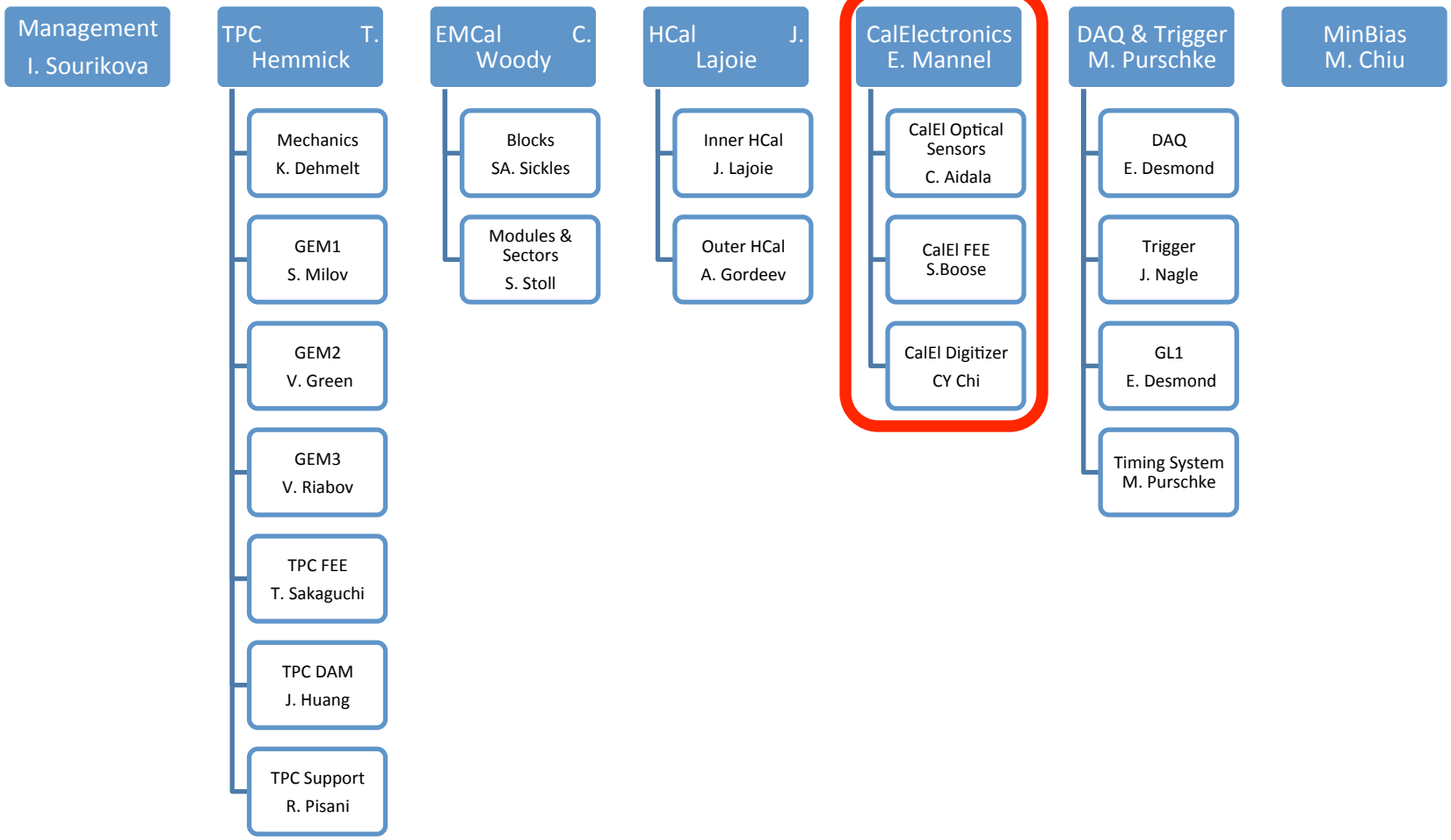


Digitizer Module

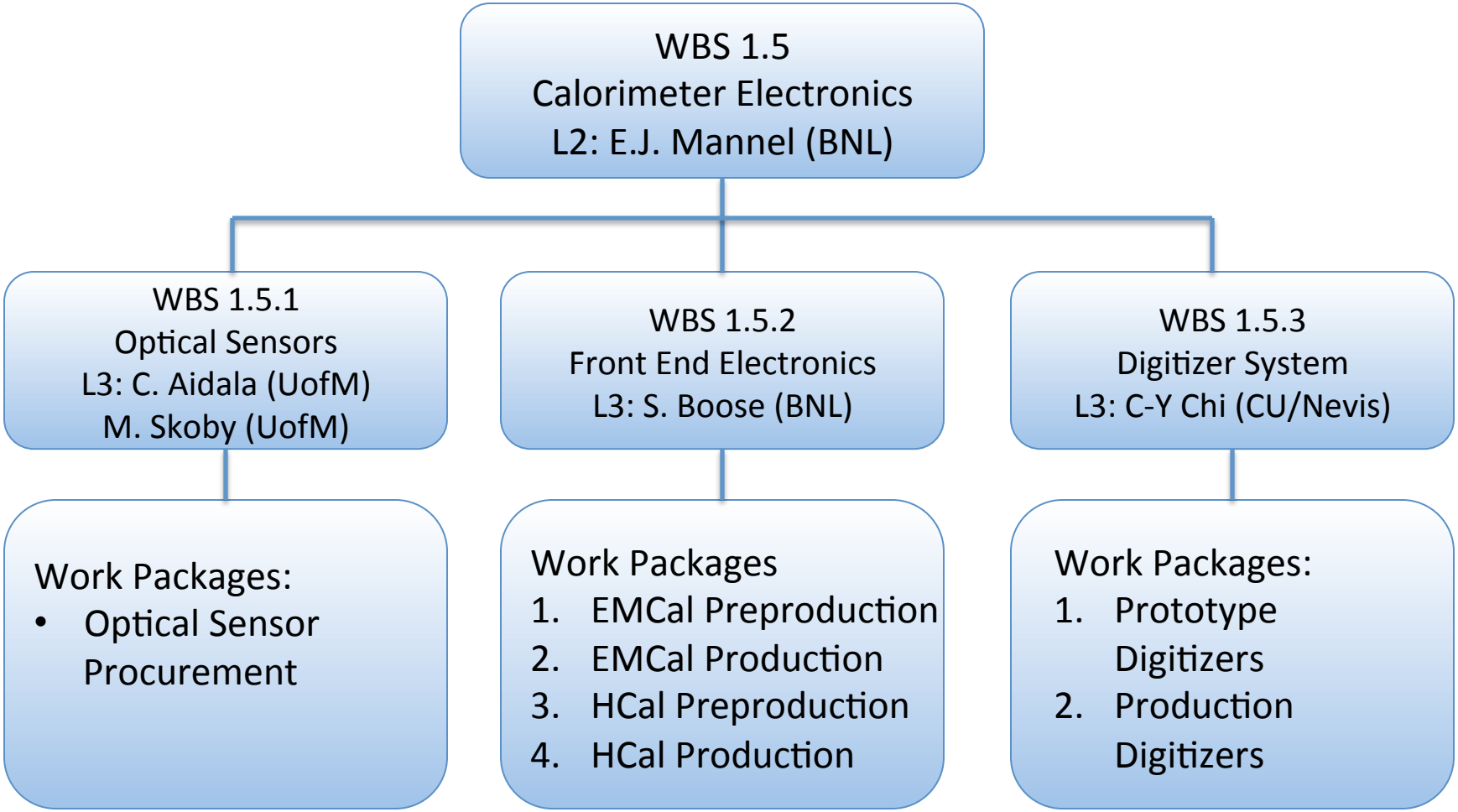
2x8 EMCal Preamp Module



Organizational Chart



WBS 1.5 Organization

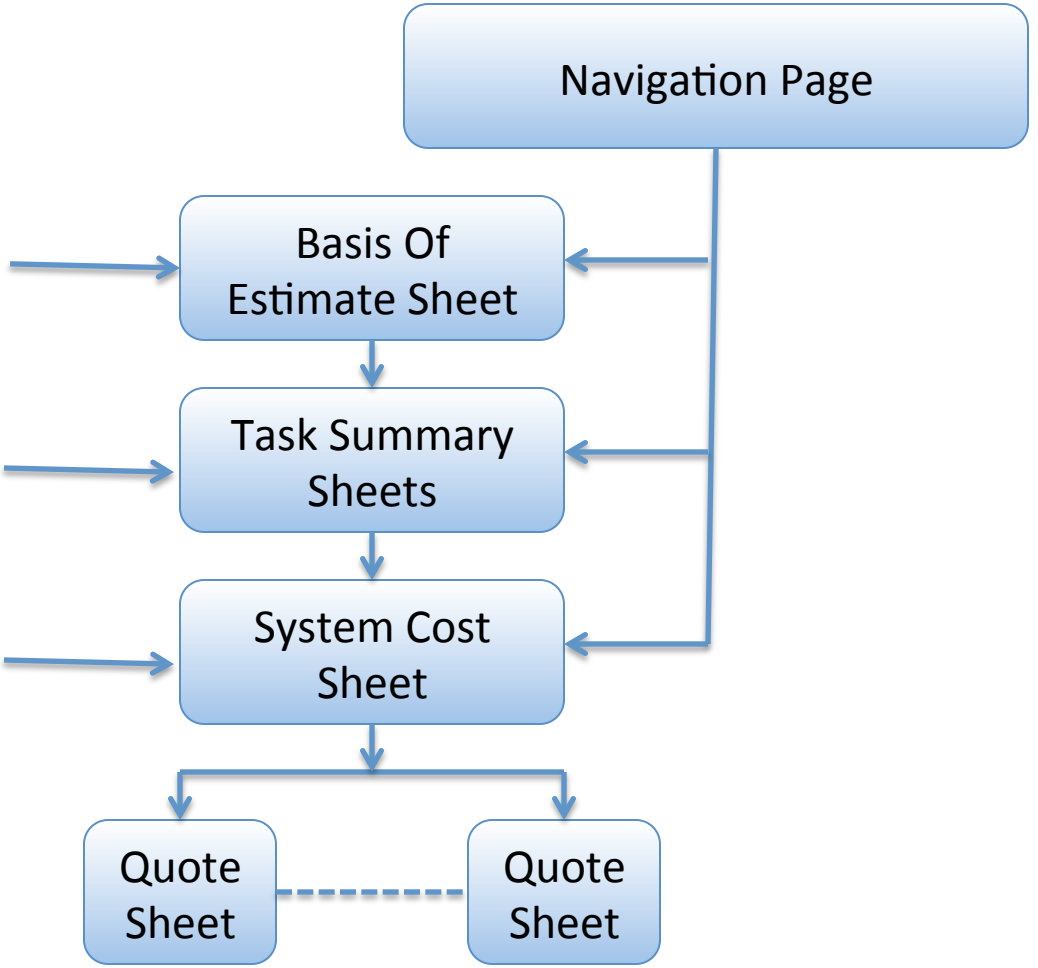


BoE Document Overview

Defines the work package assumptions used, and package cost

Defines the tasks for the work package, estimates labor for each task, and cost for task

Defines the M&S costs for the system, adds contingency



WBS 1.5 BoE Example: Navigation Page

sPHENIX Detector
Relativistic Heavy Ion Collider
BASIS of ESTIMATE (BoE)

L2 Project Name	L2 WBS Number	L3 Project Name (Control Account)	L3 WBS Number
Calorimeter Electronics	1.5	Calorimeter Frontend Electronics	1.5.2

Work Package Name	WBS Number	Basis of Estimate Link
EMCal Electronics: Preproduction Prototype	1.5.2.1	WBS1.5.2.1 Basis of Estimate
HCal Electronics: Preproduction Prototype	1.5.2.2	WBS1.5.2.2 Basis of Estimate
EMCal Electronics: Production	1.5.2.3	WBS1.5.2.3 Basis of Estimate
HCal Electronics: Production	1.5.2.4	WBS1.5.2.4 Basis of Estimate
EMCal Preproduction Prototype Tasks	1.5.2.1	WBS1.5.2.1 Tasks
EMCal Production Prototype Tasks	1.5.2.2	WBS1.5.2.2 Tasks
HCal Preproduction Prototype Tasks	1.5.2.3	WBS1.5.2.3 Tasks
HCal Production Prototype Tasks	1.5.2.4	WBS1.5.2.4 Tasks
WBS 1.5.2 System Costing	1.5.2	WBS1.5.2 System Costs

Control Account	Description
Calorimeter Frontend Electornics	This account is responsible for the design, layout, procurement of all components, assembly and Q/A testing of the front end electronics for the EMCal and HCal preproduction and production electronics.

WBS 1.5 BoE Example: BoE Page 1

Identify what was used for estimating the cost and links to additional information

	sPHENIX Detector Relativistic Heavy Ion Collider BASIS of ESTIMATE (BoE)	Date of Est:	3/20/2017
		Prepared By:	E. J. Mannel
		DocNo. (refer Rev.	DocDB-66

Work Package Name:	WBS Number:	Control Account Number
EMCal Electronics: Preproduction Prototype	1.5.2.1	

WBS Dictionary Definition:

The work package covers the design, layout, fabrication and Q/A testing of the EMCal preproduction prototype electroncs. It will deliver a total of 384 channels of EMCal frontend electornics.

Estimate Type (check all that apply):

____	Work Complete
____	Existing Purchase Order
X	Catalog Listing or Industrial Construction Database
X	Documented Vendor Quotation based on Drawings/Sketches/Specifications
X	Budgetary Estimate by Vendor/Fabricator based on Sketches, Drawings, or other Written Correspondence
X	Engineering Estimate based on Similar Items or Procedures
X	Engineering Estimate based on Analysis
X	Expert Opinion

Supporting Documents (including but not limited to):

Task Summary
Costing

WBS 1.5 BoE Example: BoE Page 2

Assumptions used, details of the basis of estimate, work package cost and work package cost + contingency

Assumptions Used in Developing Estimate

The following assumptions were used in the estimate: 1) For designed boards, the bill of materials was used to look up catalog prices for all components. 2) Printed circuit board and assembly costs were estimated on early R&D production or production of similar design and functionality. 3) Commercial vendors are assumed for all board fabrication and assembly. 4) Costs include a 10% loss due to yield.

Details of the Base Estimate (explanation of the Work)

This work package covers the preproduction design, layout, fabrication and Q/A testing of the EMCal frontend electronics. The design and layout stages covers all modifications to earlier prototype designs. Procurement covers obtaining all quotes, placing and tracking orders, and receipt of orders. Q/A testing covers the cost of all test equipment and the testing of the fabricated modules prior to installation.

Cost Summary

Task	Cost Basis	Cost	Cost + Contingency
Parts Procurement	Catalogue/Quote/Eng Estimate	$15,371.68	$18,446.02
Board Assembly and Testing	Catalogue/Quote/Eng Estimate	$9,099.20	$11,828.96
Total Cost		$24,470.88	$30,274.98

WBS 1.5 BoE Example: BoE Page 3

Explain how the contingency was determined and the levels assumed

Contingency

M&S Contigency Rules Applied
For Parts: M3 (20%)
For Assembly: M4 (30%)

Labor Contingency Rules Applied:
BNL Labor for design, layout, assembly oversight, and testing oversight: L3 (25%)
Univeristy Students for testing: L3 (25%)

WBS 1.5 BoE Example: System Cost

WBS 1.5.2 System Costs								
Date: 5-Mar-2017								
Last Revision Date: 25-Apr-2017								
	Module	Quantity	Cost	NRE	Total Cost	Total Cost + 10%	Contingency	Total Cost + Contigency
Preproduction								
	SiPM Daughter Boards- Parts	384	3.95	500.00	2,017.67	2,219.44	0.20	2,663.33
	SiPM Daughter Boards- Assembly	384	8.00	500.00	3,572.00	3,929.20	0.30	5,107.96
	SiPM Daughter Boards- Total				5,589.67	6,148.64		7,771.29
	EMCal Preamp Boards- Parts	24	217.38	500.00	5,717.22	6,288.94	0.20	7,546.73
	EMCal Preamp Boards- Assembly	24	100.00	500.00	2,900.00	3,190.00	0.30	4,147.00
	EMCal Preamp Boards- Total				8,617.22	9,478.94		11,693.73
	EMCal Interface Boards- Parts	6	439.49	500.00	3,136.96	3,450.65	0.20	4,140.78
	EMCal Interface Boards- Assembly	6	100.00	500.00	1,100.00	1,210.00	0.30	1,573.00
	EMCal Interface Boards- Total				4,236.96	4,660.65		5,713.78
	EMCal Controller Boards- Parts	2	312.26	500.00	1,124.52	1,236.97	0.20	1,484.36
	EMCal Controller Boards- Assembly	2	100.00	500.00	700.00	770.00	0.30	1,001.00
	EMCal Controller Boards- Total				1,824.52	2,006.97		2,485.36
	EMCal Controller Crate	1	1,211.71		1,211.71	1,332.88	0.20	1,599.46
	EMCal Power Supplies				0.00	0.00	0.20	0.00
	EMCal Cables- Internal	1	280.00		280.00	308.00	0.20	369.60
	EMCal Cables- External	1	486.18		486.18	534.80	0.20	641.76
	Misc Total				1,977.89	2,175.68		2,610.81
	Total Part Cost				13,974.26	15,371.68		18,446.02
	Total Assembly Cost				8,272.00	9,099.20		11,828.96
	Total EMCal Front End Electronics Cost				22,246.26	24,470.88		30,274.98

WBS 1.5 Example: Task Summary

WBS: 1.5.2.1
EMCal Electronics: Preproduction Prototype
Date: 28-Feb-2017
Last Revision Date: 25-Apr-2017

WBS	Task	Task Description	Duration (d)	Scientist		Engineer		Designer		Technician		Trades		Student		Materials and Supplies	Risk Code	
				FTE	days	FTE	days	FTE	days	FTE	days	FTEs	days	FTEs	days		Labor	Material
1.5.2.1.13	Safety and Design Review: EMCal Preproduction Electronics	This task covers the preperation and particiaption in a design and safety review for the EMCal preproduction electronics	10 days	0.25	10	0.25	10	0.25	5.00								L2	
1.5.2.1.14	Safety and Design Review Complete: EMCal Preproduction Electronics	Milestone	0 days															
1.5.2.1.15	Review Safety and Design Review Report	Review the outcome of the Dsafety and Design review and address any concerns in the design.	10 days	0.25	10	0.25	10										L2	
1.5.2.1.16	Procure Components for EMCal SiPM and Preamp Boards: Preproduction Prototype	This task covers the procurement of all components need for assembly of the EMCal SiPM Daughter board and Preamp board. Deliverables are assembly kits and documentation necessary for final assembly	30 days			0.20	10			0.25	15					8,508.38	L3	M3
1.5.2.1.17	Procure Components for EMCal Interface Board: Preproduction Prototype	This task covers the procurement of all components need for assembly of the EMCal Interface board. Deliverables are assembly kits and documentation necessary for final assembly	30 days			0.20	10			0.25	15					3,450.65	L3	M3
1.5.2.1.18	Procure Components for Calorimeter Controller Boards: Preproduction Prototype	This task covers the procurement of all components need for assembly of the EMCal/HCal Controller board. Deliverables are assembly kits and documentation necessary for final assembly	30 days			0.20	10			0.25	15					1,236.97	L3	M3
1.5.2.1.19	Procure EMCal Signal and Power Cables, and Power Systems: Preprodcution Prototype	This task covers the procurement of all cables (signal, control, power and bias) and power systems needed for the EMCal prototype.	40 days			0.20	10			0.25	15					2,175.68	L3	M3
1.5.2.1.20	Assemble and Test EMCal SiPM Daughter Boards and Preamp Boards: Preproduction Prototype	This task covers the assembly and testing of the EMCal SiPM daughter boards and Preamps required for the preproduction EMCal 1/2 sector . Deliverables are the SiPM Daughter boards and Preamps for 384 towers.	35 days			0.20	15			0.25	15					7,119.20	L3	M4
1.5.2.1.21	Assemble and test EMCal Interface Boards: Preproduction Prototype	This task covers the assembly and testing of the EMCal Interface boards required for the preproduction EMCal 1/2 sector . Deliverables are the Interface boards for 384 towers.	30 days			0.20	15			0.25	15					1,210.00	L3	M4
1.5.2.1.22	Assemble and test calorimeter controller boards: Preproduction Prototype	This task covers the assembly and testing of the EMCal Controller boards required for the preproduction EMCal 1/2 sector . Deliverables are the Controller boards for 384 towers	30 days			0.50	20			0.25	15					770.00	L3	M4
1.5.2.1.23	Review and Write EMCal Electronics Design Change Specifications: Preproduction Prototype	This task cover the reviewing the EMCal Preproduction prototype electronics system testing and performance and write any design changes required for production electronics.	10 days	0.25	10	0.25	10										L3	
1.5.2.1.24	EMCal Electronics Review Complete: Preproduction Protoype	Milestone	0 days															
1.6.1	Total Cost:			2.00	65.00	6.45	295.00	2.25	55.00	1.75	105.00	0.00	0.00	0.00	0.00	24,470.88		

WBS 1.5 BoE Example: Detailed Cost Estimate

- Detailed module estimates
- Based on BoMs
- Used for system costing
- Available in BoE documents

sPHENIX Hadronic Preamp Dual-Range Revised: Monday, December 19, 2016
Hadronic_Preamp_DUAL-RANGE-F.DSN Revision: F
Last Revision Date: 25-Apr-2017

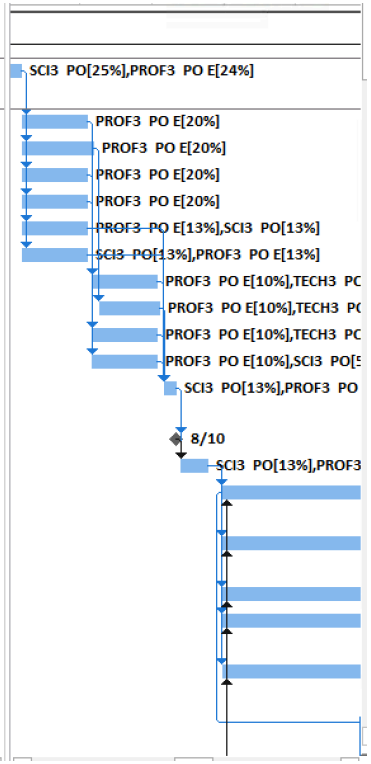
Item	Quantity	Reference	Part	PCB Footprint	Unit Cost	Total
1	1	C1	1uF	CC0805	0.108	0.108
2	2	C2,C3	10uF	CC0603	0.072	0.144
3	5	C4,C7,C25,C28,C34	10nF	C0402	0.003	0.015
4	19	C5,C6,C8,C11,C14,C18,C19,C20,C21,C23,C26,C27,C29,C33,C35,C37,C38,C40,C41	100nF	C0402	0.003	0.057
5	4	C9,C13,C24,C30	1uF	C0402	0.015	0.059
6	4	C10,C22,C32,C39	1nF	C0402	0.003	0.012
7	1	C12	10pF	C0402	0.003	0.003
8	2	C15,C31	47nF	C0402	0.003	0.006
9	1	C16	180pF	C0402	0.003	0.003
10	1	C17	100pF	C0402	0.003	0.003
11	1	C36	1pF	C0402	0.004	0.004
12	1	HDR1	CON2	HDR2	0.044	0.044
13	1	J1	DF11-10DP-2DS	DF11-10DP	0.728	0.728
14	6	SI1,SI2,J2,SI3,SI4,SI5	DF3A-3P-2DS	DF3A-3P-2DS	0.080	0.480
15	1	L1	180nH	CC0603	0.034	0.034
16	2	Q1,Q2	BFR93AW	SOT323	0.107	0.214
17	1	Q3	NTS4409N	SOT323	0.099	0.099
18	1	RT1	KS103J2	HDR2/2MM	2.390	2.390
19	1	R1	100R	C0402	0.001	0.001
20	3	R2,R12,R22	10R	C0402	0.001	0.003
21	3	R3,R21,R25	1.02K	C0402	0.001	0.003
22	4	R4,R11,R13,R16	49R9	C0402	0.001	0.004
23	2	R5,R19	5.9K	C0402	0.001	0.002
24	2	R6,R26	27R	C0402	0.001	0.002
25	2	R7,R20	261R	C0402	0.001	0.002
26	1	R8	220R	C0402	0.001	0.001
27	3	R9,R17,R24	10K	C0402	0.001	0.003
28	2	R10,R14	249R	C0402	0.001	0.002
29	1	R15	DNP	C0402	0.000	0.000
30	2	R18,R27	750R	C0402	0.041	0.082
31	1	R23	27K	C0402	0.001	0.001
32	1	R28	140R	C0402	0.001	0.001
33	1	R29	620R	C0402	0.041	0.041
34	1	R30	20R	C0402	0.041	0.041
35	2	U1,U4	AD8001ART	SOT23-5	1.635	3.270
36	1	U2	ADG601	SOT23-6	1.185	1.185
37	1	U3	AD8132ARM	MSOP8	2.217	2.217
38	1	U5	ADG602	SOT23-6	1.362	1.362
	1	Blank Board			8.000	8.000
	1	Assy			50.000	50.000
			Unit	Total		70.625
				Total Parts Cost		20.625
				Total Assembly Cost		50.000
				Total Board Cost		70.625
				NRE		500.000

WBS Dictionary

1.5				**SPHENIX CALORIMETER ELECTRONICS**	The Calorimeter Electronics for the sPHENIX Experiment at RHIC
1.5	1.5.1			**Optical Sensors**	This work packages covers the procurement and Q/A testing of the preproduction and production optical sensors for the EMCal and HCal detectors.
1.5	1.5.2			**Calorimeter Front End Electronics**	This covers the design, fabrication and Q/A testing of the preproduction and production calorimeter front end electronics.
1.5	1.5.2	1.5.2.1		**EMCal Electronics: Preproduction Prototype**	The work package covers the design, layout, fabrication and Q/A testing of the EMCal preproduction prototype electronics. It will deliver a total of 384 channels of EMCal frontend electronics.
1.5	1.5.2	1.5.2.2		**EMCal Electronics: Production**	The work package covers the design, layout, fabrication and Q/A testing of the EMCal production electronics. It will deliver a total of 24576 channels of EMCal frontend electronics.
1.5	1.5.2	1.5.2.3		**HCal Electronics: Preproduction Prototype**	The work package covers the design, layout, fabrication and Q/A testing of the HCal preproduction prototype electronics. It will deliver a total of 48 channels of HCal frontend electronics.
1.5	1.5.2	1.5.2.4		**HCal Electronics: Production**	The work package covers the design, layout, fabrication and Q/A testing of the HCal production electronics. It will deliver a total of 3072 channels of HCal frontend electronics.
1.5	1.5.3			**Calorimeter Digitizer System**	This covers the design, fabrication and Q/A testing of the preproduction and production calorimeter digitizer electronics.
1.5	1.5.3	1.5.3.1		**Calorimeter Digitizer: Preproduction Prototype**	This work package covers the final design, layout and fabrication for the preproduction digitizers needed for the sPHENIX EMCal and HCal detectors. The EMCal requires a total of 364 channels, and the HCal requires a total of 48 channels
1.5	1.5.3	1.5.3.2		**Calorimeter Digitizers: Production**	This work package covers the final design, layout and fabrication for the production digitizers needed for the sPHENIX EMCal and HCal detectors. The EMCal requires a total of 24576 channels, and the HCal requires a total of 3072 channels. The Digitizer System consists of the 64 channel ADC Digitizer boards, XMIT boards, Controller boards, Clock Masters Boards, Trigger Transmitter Modules, Crates, associated power supplies, and patch fibers from the digitizer crates to the local patch panel in the 1008 interaction region.

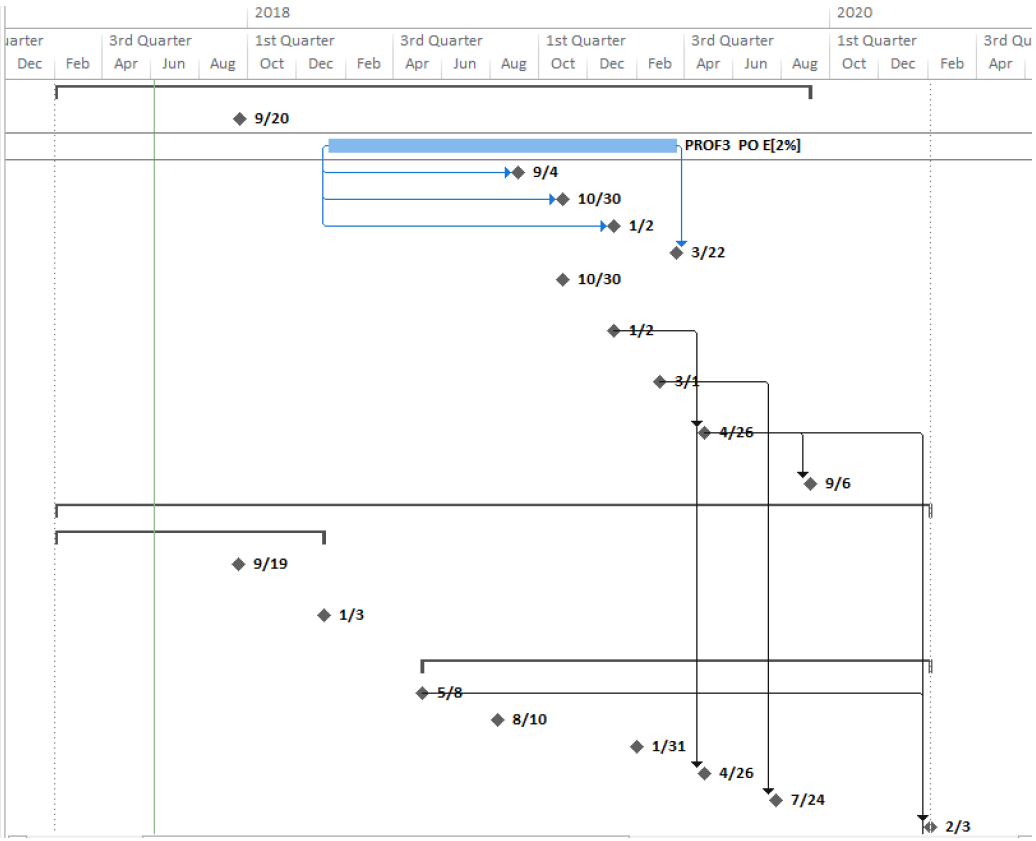
Resource Loaded Schedule

1.5.2.2	**EMCal Electronics: Production**			**432 days**	**$1,042,100.00**	**$1,300,777.45**
1.5.2.2.1	L3 Oversight: EMCal Electronics Production	205FS-80 days,47	85	0 days	$0.00	$0.00
1.5.2.2.2	Review and Write EMCal Electronics Design Specification: Production	205FS-80 days,47	54,56,57,58,59,55	20 days	$0.00	$8,309.86
1.5.2.2.3	Design EMCal SiPM Daugher Board: Production	53	60	20 days	$0.00	$2,874.88
1.5.2.2.4	Design EMCal Preamp: Production	53	61	21 days	$0.00	$3,018.62
1.5.2.2.5	Design Calorimeter Controller: Production	53	62	20 days	$0.00	$2,874.88
1.5.2.2.6	Design EMCal Interface: Produciton	53	63	20 days	$0.00	$2,874.88
1.5.2.2.7	Specify signal and power cables for EMCal: Production	53	64	20 days	$0.00	$4,395.87
1.5.2.2.8	Specify power system for EMCal: Production	53	64	20 days	$0.00	$4,395.87
1.5.2.2.9	Layout EMCal SiPM Daughter Board: Production	54	64	20 days	$0.00	$7,925.44
1.5.2.2.10	Layout EMCal Preamp: Production	55	64	20 days	$0.00	$7,925.44
1.5.2.2.11	Layout Calorimeter Controller: Production	56	64	20 days	$0.00	$7,925.44
1.5.2.2.12	Layout EMCal Interface: Production	57	64	20 days	$0.00	$11,157.44
1.5.2.2.13	Production Readiness and Safety Review: EMCal Production Electronics	59,60,61,62,63,58	65,66	5 days	$0.00	$1,520.69
1.5.2.2.14	Production Readiness & Safety Review: EMCal Electronics	64	66	0 days	$0.00	$0.00
1.5.2.2.15	Review EMCal Production Readiness and Safety Review	64,65	67,68,69,71,70	10 days	$0.00	$2,197.94
1.5.2.2.16	Procure Components: SiPM and Preamp Boards: Production.	66,205,50	72SS	80 days	$394,000.00	$403,510.53
1.5.2.2.17	Procure components: Calorimeter Controller Boards: Production.	66,205,50	84	80 days	$36,500.00	$47,160.48
1.5.2.2.18	Procure components: EMCal Interface Board: Production.	66,205,50	78	80 days	$22,000.00	$32,660.48
1.5.2.2.19	Procure Internal EMCal Signal and Power Cables: Production	66,205		220 days	$11,200.00	$26,891.52
1.5.2.2.20	Procure EMCal External Signal and Power Cables, and Power Systems: Production	66,205,50	85	220 days	$431,000.00	$456,734.72
1.5.2.2.21	Assemble and Test SiPM Daughter Boards: Production.	67SS,15SS	85,73SS+60 days,75SS+120	310 days	$54,100.00	$144,121.52



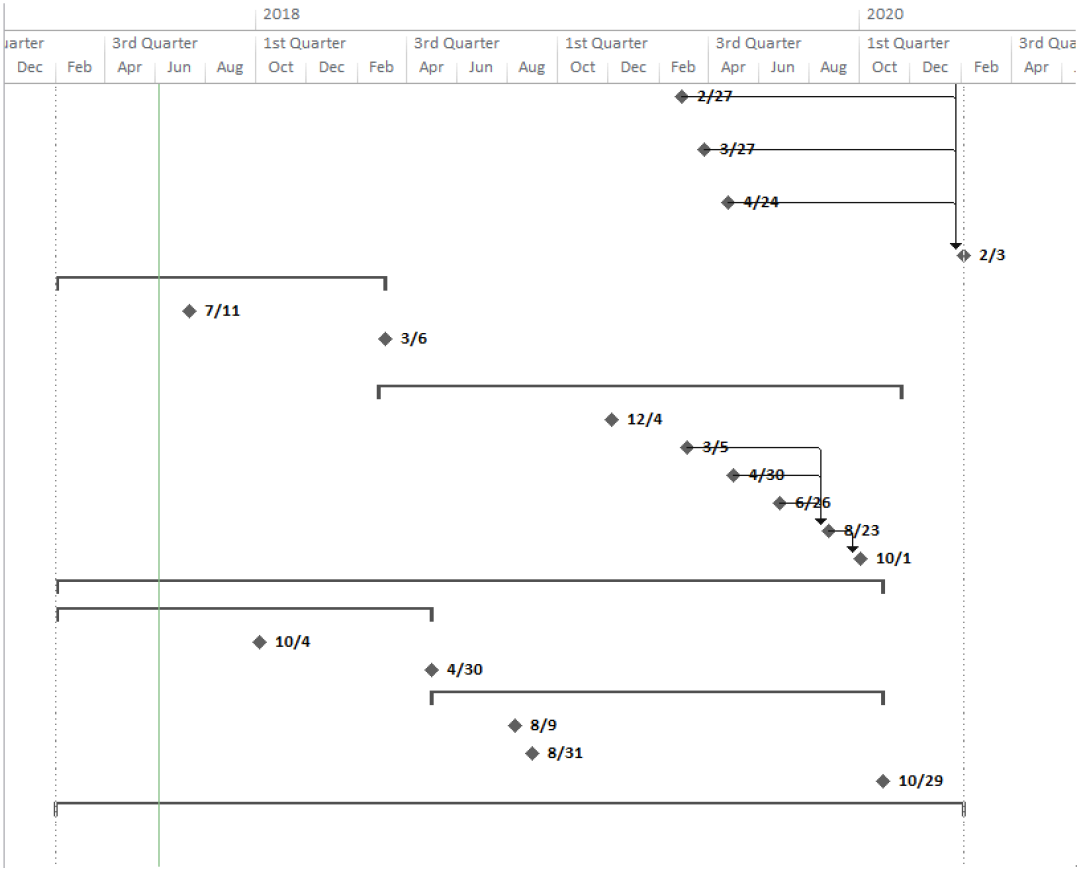
WBS 1.5 Milestones-I

WBS	Name
1.5.1	**Optical Sensors**
1.5.1.6	EMCal/HCal Sensors Tested and Delivered: Preproduction
1.5.1.8	Order Sensors: Production
1.5.1.9	25% Sensors Received: Production
1.5.1.10	50% Sensors Received: Production
1.5.1.11	75% Sensors Received: Production
1.5.1.12	Sensors: Production Complete
1.5.1.14	25% Sensors Q/A Tested & Delivered: Production
1.5.1.15	50% Sensors Q/A Tested & Delivered: Production
1.5.1.16	75% Sensors Q/A Tested & Delivered: Production
1.5.1.17	EMCal/HCal Sensors Tested and Delivered: Production
1.5.1.18	Optical Sensor Procurement Complete
1.5.2	**Calorimeter Front End Electronics**
1.5.2.1	**EMCal Electronics: Preproduction Prototype**
1.5.2.1.14	Safety and Design Review Complete: EMCal Preproduction Electronics
1.5.2.1.24	EMCal Electronics Review Complete: Preproduction Protoype
1.5.2.2	**EMCal Electronics: Production**
1.5.2.2.1	L3 Oversight: EMCal Electronics Production
1.5.2.2.14	Production Readiness & Safety Review: EMCal Electronics
1.5.2.2.22	25% EMCal SiPM Daughter Boards Delivered: Production
1.5.2.2.23	50% EMCal SiPM Daughter Boards Delivered: Production
1.5.2.2.24	75% EMCal SiPM Daughter Boards Delivered: Production
1.5.2.2.25	100% EMCal SiPM Daughter Boards Delivered: Production



WBS 1.5 Milestones-II

WBS	Name
1.5.2.2.28	50% EMCal Preamp and Interface Boards Delivered-Production
1.5.2.2.29	75% EMCal Preamp and Interface Boards Delivered-Production
1.5.2.2.30	100% EMCal Preamp and Interface Boards Delivered-Pproduction
1.5.2.2.32	EMCal Electronics Complete: Production
1.5.2.3	**HCal Electronics: Preproduction Prototype**
1.5.2.3.16	HCal Electronics Safety Review
1.5.2.3.28	HCal Preproduction Electronics Complete
1.5.2.4	**HCal Electronics: Production**
1.5.2.4.16	Hcal Frontend Electronics Production Review
1.5.2.4.25	25% Hcal SiPM & Preamp Boards complete: Production
1.5.2.4.26	50% Hcal SiPM & Preamp Boards complete: Production
1.5.2.4.27	75% Hcal SiPM & Preamp Boards complete: Production
1.5.2.4.28	Hcal SiPM & Preamp Boards Complete: Production
1.5.2.4.32	HCal Electronics Complete: Production
1.5.3	**Calorimeter Digitizer System**
1.5.3.1	**Calorimeter Digitizer: Preproduction Prototype**
1.5.3.1.13	Calorimeter Digitizer Safety Review Complete
1.5.3.1.19	Calorimeter Digitizer Preproduction Complete
1.5.3.2	**Calorimeter Digitizers: Production**
1.5.3.2.12	Calorimeter Digitizer Readiness & Safety Review Complete
1.5.3.2.14	Calorimeter Digitizer Procurement Start
1.5.3.2.18	Calorimeter Digitizer Production Complete
1.5.4	**Project Management**



Risk Registry

E. Mannel	1.5 Cal Electronics	Delay in SiPM Delivery	SiPM order not placed on schedule or vendor unable to meet production schedule	Delay in assembly of HCal and EmCal SiPM daughter boards. Potential delay in HCal and EMCal module assembly	Procurement	Moderate: 50%	Low: Schedule delay 2-3 months	Low	Closely monitor the procurement stage.
E. Mannel	1.5 Cal Electronics	Delay in testing of SiPMs	SiPM Delivery not placed on schedule or vendor unable to meet prodcution schedule	Delay in assembly of HCal and EMCal SiPM daughter boards. Potential delay in HCal and EMCal module assembly	Production	Moderate: 50%	Low: Schedule delay 2-3 months	Low	Increase number of testing stations. Identify additional collaborators who can contribute to the testing program. Streamline testing program.
E. Mannel	1.5 Cal Electronics	Delay in Assembly of HCal Daughter boards, Preamps, Interface boards, LED Drivers	Procurement of components, issuing of orders.	Potential delay in HCal module assembly and testing	Production	Moderate: 25%	Low: Schedule delay 2-3 months	Low	Staged partial deliveries of boards. Use multiple assembly houses
E. Mannel	1.5 Cal Electronics	Delay in assembly of EMCal Daughter boards, Preamps or Interface boards	Procurement of components, issuing of orders.	Potential delay in EMCal module assembly and testing	Production	Moderate: 25%	Low: Schedule delay 2-3 months	Low	Staged partial deliveries of boards. Use multiple assembly houses

Current Status

- Well developed set of costing documents (BoEs)
- Estimates are based on current prototype designs
  - Most price estimates with in last 9 month
  - Bottoms up contingency ranging from 20%-40%
  - Advanced stage of prototyping implies low technical risk
- Cost estimates are routinely updated on recent design changes.
- On going discussions with vendors to “value engineer” where possible.